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Pollution of Ambient Air by Volatile Anesthetics: A Comparison of Four Anesthetic Management Techniques

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Abstract

Chronic exposure to waste anesthetic gas (WAG) may lead to health problems. The purpose of this study was to compare WAG concentrations resulting from four combinations of FGF and vaporizer settings during a simulated intravenous induction where the anesthetic is deepened using a volatile anesthetic delivered via mask ventilation prior to intubation.

Using lung model, WAG was sampled three times each using four different combinations and three volatile anesthetics: 3% sevoflurane, 2% isoflurane, and 6% desflurane. The combinations were FGF off/vaporizer on, FGF on/vaporizer off, leaving both on and turning both off. WAG was measured using a MIRAN Ambient Air Analyzer placed at a level approximating the anesthetist's head. One-way analysis of variance with a Student-Newman-Keuls post hoc test was used to compare the concentration of WAG among the combinations of FGF/vaporizer settings and among the agents for a given combination.

Regardless of the agent, only the FGF on/vaporizer on combination resulted in a statistically greater WAG level ($p<0.005$). The results support using three of the four combinations examined when mask ventilation with a volatile agent accompanies an intravenous induction. Future studies should examine other methods of controlling WAG levels and use time-weighted averages to help address clinical significance.

Introduction

Despite decades of research, there is no definitive evidence that trace amounts of waste anesthetic gas (WAG) cause health problems.[1] However, likely because there is no definitive evidence to the contrary and the potential severity of the health problems both to health care workers and their children, government regulations mandate monitoring of WAG concentrations in the operating room (OR) and describe WAG limits.[2] Pollution of the OR with WAG is unavoidable when volatile anesthetic are used during the routine administration of an anesthetic. Potential sources of WAG include an incomplete facemask seal, scavenging system malfunction, leakage of the gas mixture around an uncuffed endotracheal tube, and disconnection of the anesthetic circuit.[3]

An additional source of WAG is during an anesthetic induction of an adult, where anesthesia is induced with an intravenous agent and deepened with a volatile anesthetic agent prior to laryngoscopy and endotracheal intubation. In this scenario, the anesthetic agent is delivered via a facemask and the facemask is removed just prior to the laryngoscopy. Anesthesia providers commonly control the fresh gas flow (FGF) and/or adjust the vaporizer output to the patient to decrease WAG exposure during the period between removal of the facemask and reconnection of the breathing circuit to the endotracheal tube. The purpose of this study was to determine the combination of FGF/vaporizer adjustments that result in the least amount of WAG within the breathing zone of the anesthesia provider during a simulated adult intravenous induction, where the anesthetic depth is deepened with a volatile agent prior to laryngoscopy and endotracheal intubation.

Materials and Methods

After Institutional Review Board approval, the study was conducted in three ORs.

The ORs were of similar size with two having an area of 368.33 square feet and the third was 365.49 square feet. The test setup consisted of a Narkomed 4 anesthesia machine (North American Draeger, Telford, PA) with accompanying circle system with carbon dioxide absorber, standard OR table, and a lung model. A coaxial breathing circuit (King F2, King Systems, Inc., Noblesville, IN) was attached to the semiclosed circle system with a carbon dioxide absorber on the anesthesia machine. The lung model consisted of a three-liter anesthesia breathing reservoir bag (King Systems, Inc., Noblesville, IN). The breathing zone was defined as a two-foot vertical distance from the top right edge of the OR table where the anesthesia provider stands during induction and intubation of a patient. This area approximates the location of the anesthesia provider.

The air exchange for each room was verified by the hospital facilities management department to be functioning properly with 15 exchanges per hour. Prior to each data collection period, the anesthesia machine, including the scavenging system, was prepared according to the manufacturer's recommendations.

The MIRAN SapphleRe Ambient Air Analyzer (ThermoElectron Corporation, Waltham, MA) was used to measure the concentration of WAG. The MIRAN SapphleRe measures gases by infrared spectroscopy.[4] This device and other infrared spectrophotometers have been used in prior investigations to measure WAG.[5,6] The MIRAN SapphleRe reports the number of WAG gas particles in the sampled air. Each gas has a different partial pressure and thus a different wavelength frequency that can be detected by the instrument.[4] Once analyzed, the results are recorded as parts per million. The MIRAN SapphleRe was sent to the manufacturer, ThermoElectron Corporation, for calibration prior to the start of the study, to ensure accurate and precise data collection.

WAG was sampled twice in each of the three ORs using four different anesthetic management techniques and three volatile anesthetics at predetermined concentrations: 2% sevoflurane, 1% isoflurane, and 6% desflurane for a total of 72 different conditions. The four anesthetic management techniques were: turning FGF off while leaving the vaporizer on, leaving FGF on while turning the vaporizer off, leaving both on, and turning both off.

The investigators first performed a simulated intravenous induction consisting of an induction agent and a nondepolarizing muscle relaxant. While waiting for the effects of the intravenous agents during a timed two-minute period, the lung model was ventilated with an oxygen flow rate of ten liters per minute and a volatile agent at the predetermined concentration. This was done to simulate mask ventilation with a volatile agent used in conjunction with an intravenous induction. Tidal volume and respiratory rate were controlled at 500ml and 12-14 breaths per minute, respectively.

After this two-minute interval elapsed, the investigators simulated intubating the patient/lung model. This consisted of a thirty-second period where the breathing bag was clamped, disconnected from the anesthesia circuit, and the circuit was placed on the tube tree at the top right hand side of the OR table. At the beginning of this thirty-second intubation phase, the anesthetic management technique was implemented, i.e., one of the four FGF/vaporizer combinations.

Immediately after the thirty-second intubation period, the anesthesia circuit was reattached to the lung model, simulating the reattachment of the circuit to an endotracheal tube. Just prior to reattachment of the circuit to the lung model, the air in the breathing zone was measured for quantity of anesthetic agent by the MIRAN SapphleRe. The

MIRAN SapphleRe also recorded WAG concentrations one minute after the circuit was reattached to the patient/lung model.

Statistical analysis was accomplished with the assistance of commercially available software package (SPSS for Windows, Release 11.0, SPSS, Inc, Chicago, IL)[7] One way analysis of variance with Student-Newman- Keuls post hoc test was used to compare the concentrations of WAG present in the breathing zone. The four techniques were compared to each other for each of the volatile agents at the thirty- and sixty-second time intervals.

Results

Mean concentrations of WAG concentrations at thirty and sixty-seconds for the four management techniques and three concentrations are shown in Tables 1 and 2. Regardless of the volatile agent or anesthetic management technique, only the FGF on/vaporizer on technique yielded a statistically different WAG level ($p<0.005$) at sixty seconds. These results were significantly higher than the other three anesthetic management techniques, which were not significantly different from each other. For each agent, the results at sixty seconds were not statistically different with those at thirty seconds, indicating a low likelihood of an interaction between technique and time.

Discussion

The effect of WAG exposure to OR personnel is controversial and has been reviewed by many authors.[1,8,9] Potential adverse health effects include hepatotoxicity, adverse effects on DNA, teratogenicity, effects on neurobehavior, and miscarriage.[8] Many of the epidemiological studies suffer from varying degrees of methodological problems. However, as pointed out by one group, when the epidemiological studies are considered with animal and *in vitro* investigations, both governmental agencies and

practitioners indicate procedures should be in place to limit the exposure of personnel to WAG.[8]

The findings of this investigation demonstrated that only leaving both the FGF and the vaporizer on yielded statistically different WAG concentrations at only the sixty seconds post-intubation measurement. It was expected that this technique would yield higher WAG concentrations at both the thirty and sixty second intervals. Interestingly, the other three techniques demonstrated reduced WAG concentrations, but were not significantly different from each other at both the thirty- and sixty-second intervals.

Turning the FGF off and leaving the vaporizer on likely limited the WAG concentration due to the lack of carrier gas flow to propel the anesthetic agent into the breathing zone. Turning the vaporizer off and leaving the FGF on had a similar effect of WAG by stopping the emission of anesthetic agent and/or diluting the anesthetic agent into the continued FGF. Turning both the vaporizer and the FGF off had an effect on WAG similar to the maneuvers being performed separately.

Contamination of the OR by WAG has been examined and reviewed by other investigators.[3, 10] Studies were typically conducted during induction of anesthesia using a volatile agent, often in pediatric patients. Sources of contamination included leakage due to a poor facemask seal, problems with the scavenging system, leakage around an uncuffed endotracheal tube, and leakage due to equipment malfunction.[3] Previous investigations did not examine the optimal FGF/vaporizer maneuver to limit WAG during the period between the end of mask ventilation and endotracheal intubation. Avoiding the use of a volatile anesthetic agent and/or nitrous oxide while ventilating the patient using a facemask does reduce the time weighted exposure of personnel to volatile

agents.[10] However, the controllability, efficacy, and convenience of the volatile agents makes these an attractive option to deepen the anesthetic level after an intravenous induction.

The present findings support the clinician not leaving both the FGF and the vaporizer on during laryngoscopy and intubation. These findings support the previous recommendations of reducing occupational exposure to inhalation anesthetics.[9] This author also empirically recommended emptying the breathing bag and turning off the flow of nitrous oxide and the vaporizer.

This study was a preliminary investigation and used a relatively limited number of conditions. This study was conducted in a mid-sized hospital in the southeastern United States that had undergone various phases of restorations, including the air exchanger system. Two of the three ORs used in the study were the exact same size, while the third room was slightly smaller; this may have altered the measurements in the smaller room.

The use of a lung model cannot account for the uptake and distribution of volatile anesthetic that would occur in an actual patient scenario. Therefore it does not account for what minimal amount of volatile agent that could leave the patient's airway and contribute to the amount of WAG in the atmosphere during the intubation period. Measurements in this study may be slightly higher than what would be found in a real life scenario. Future investigations should be conducted using an actual patient. In addition, time weighted averages should be examined rather than periodic measurements.

Anesthesia providers should be cautious about WAG and limit exposure to these agents. The results of this investigation support providers using one of three techniques

to limit WAG exposure. Anesthesia providers should consider adopting the technique that best fits in their practice.

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Figure Legend

Figure 1: Mean waste anesthetic gas concentrations in breathing zone at 30-seconds post-intubation[1]

Figure2: Mean waste anesthetic gas concentration in breathing zone at 60-seconds post-intubation[2]

Figure 1

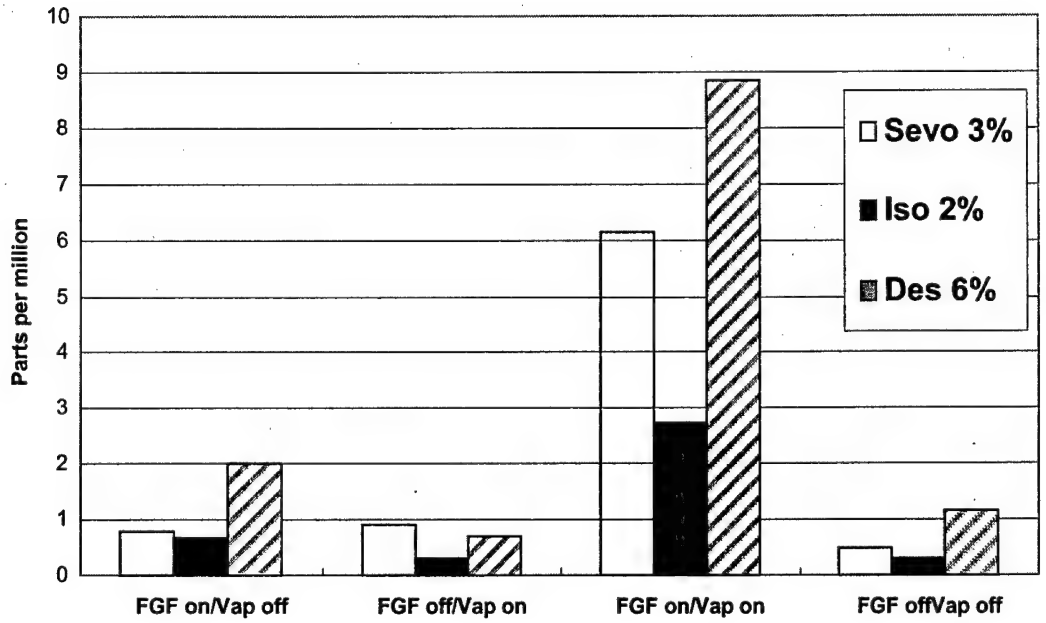
10
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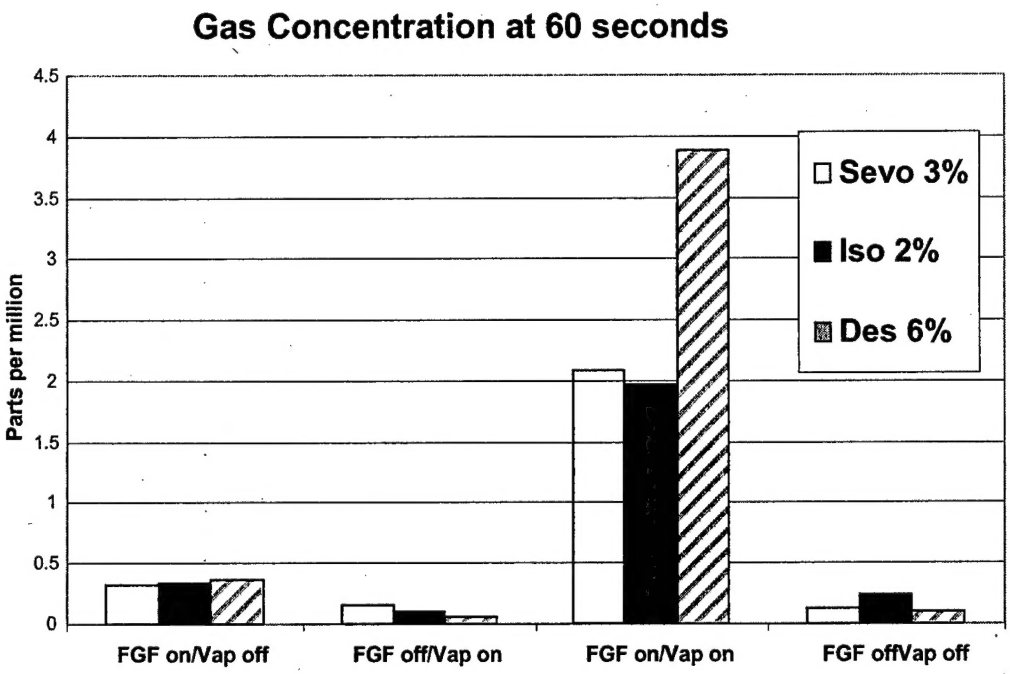
Figure 2


Gas Concentration at 60 seconds
Parts per million
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4
3.5
3
2.5
2
1.5
1
0.5
0
Sevo 3%
Iso 2%
Des 6%
FGF on/Vap off
FGF off/Vap on
FGF on/Vap on
FGF offVap off

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Short Biographical Sketch

Captain Joy Barberio, SRNA, BSN, NC, USAF, and Captain Jason Bolt, SRNA, BSN, NC, USAF are nurse anesthesia students, Nurse Anesthesia Program, Graduate School of Nursing, Uniformed Services University of the Health Sciences, Bethesda, MD. They are completing Phase II Clinical Training at Keelser AFB Medical Center at Keelser AFB, MS.

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LtCol Paul Austin is an Associate Professor, Graduate School of Nursing, Uniformed Services University of the Health Sciences, Nurse Anesthesia Program.

DEPARTMENT OF THE AIR FORCE
AIR EDUCATION AND TRAINING COMMAND

7 December 2004

MEMORANDUM FOR MS TAMIKO ALEXANDER/AFIT/CIMI

FROM: 81MSGS/SGCQJ AFB MS

SUBJECT: Research Completion Paperwork for USU Nurse Anesthesia Residents Class 2004 at Keesler AFB

1. Enclosed are copies of the research projects/papers that are to be submitted for publication, conducted in the Uniformed Services University Nurse Anesthesia Program by Capt Joy Barberio, Capt Robert Bland, Capt Jason Bolt and Capt David Perkins. Also included is the "SECURITY AND POLICY REVIEW WORKSHEET-Request for Public Release Clearance" forms.

2. I also verify the research and papers have been approved by the respective committee members.

Please let me know if you have any questions. I can be reached at DSN 597-6367 or email william.craig@keesler.af.mil

WILLIAM JOHN CRAIG, Major, USAF, NC
Dir, Nurse Anesthesia Clinical Training